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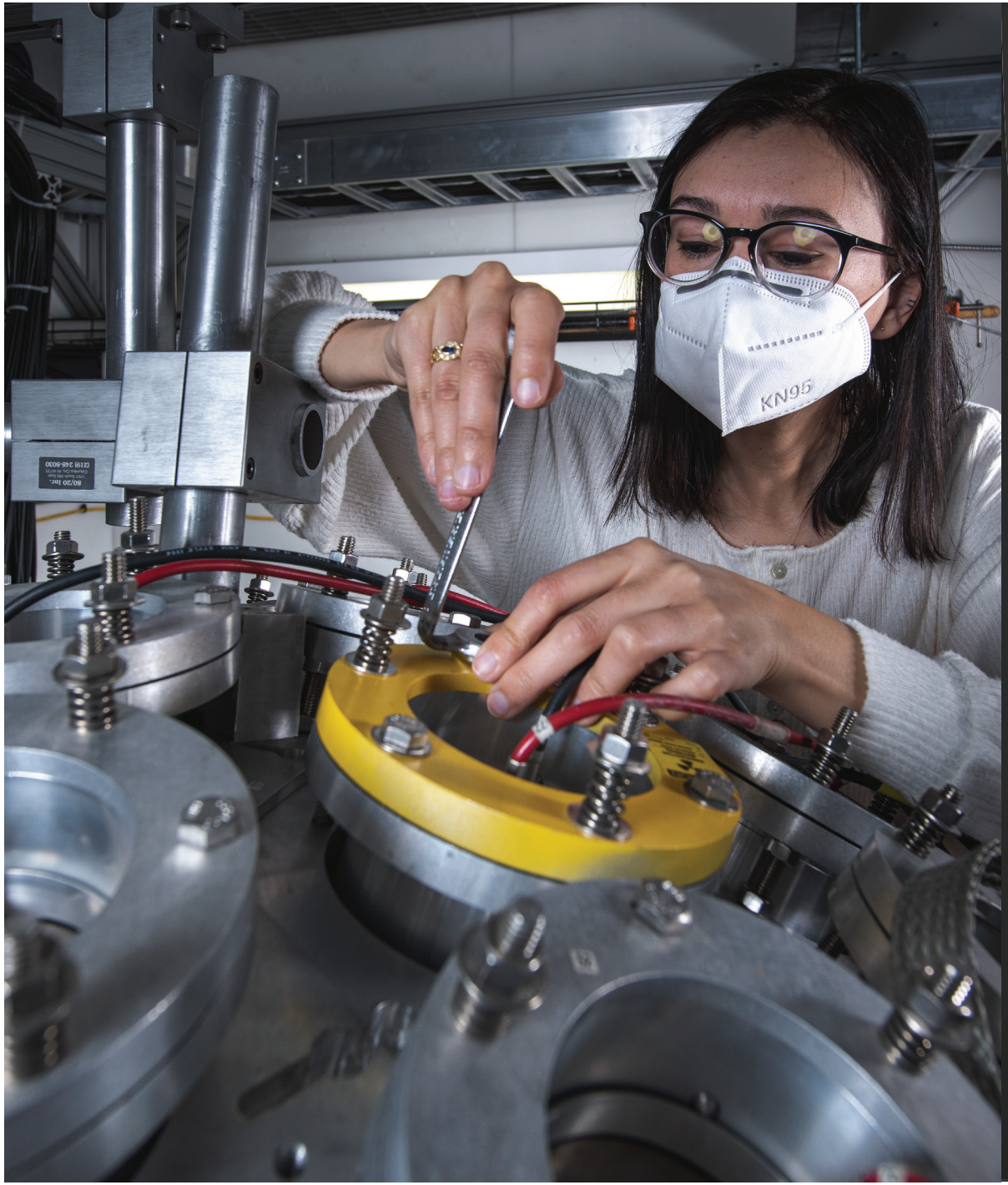

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^{233}U(n,γ) measurements in the Unresolved and Fast Regime at LANSCE

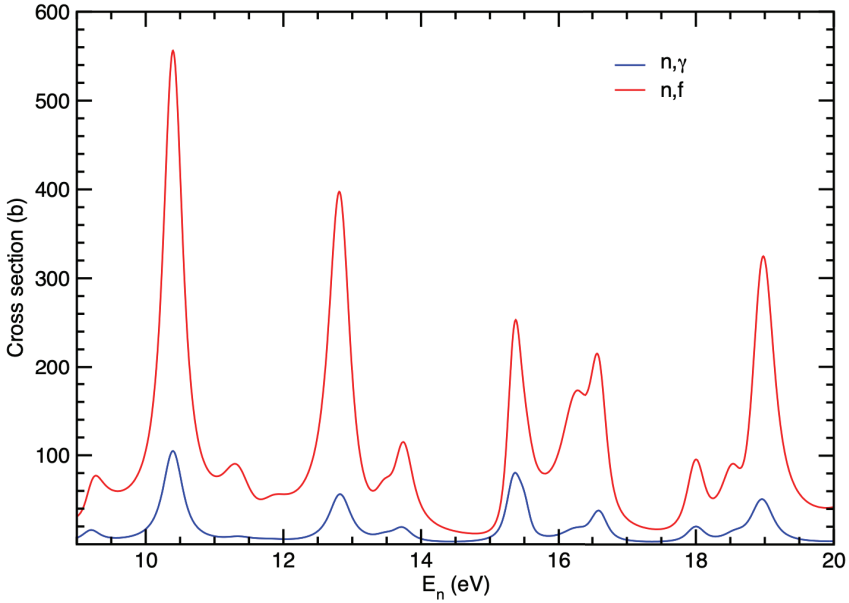
NCSP Site Visit

A. Couture and E. Leal Cidoncha

19 Jan 2022

Motivation

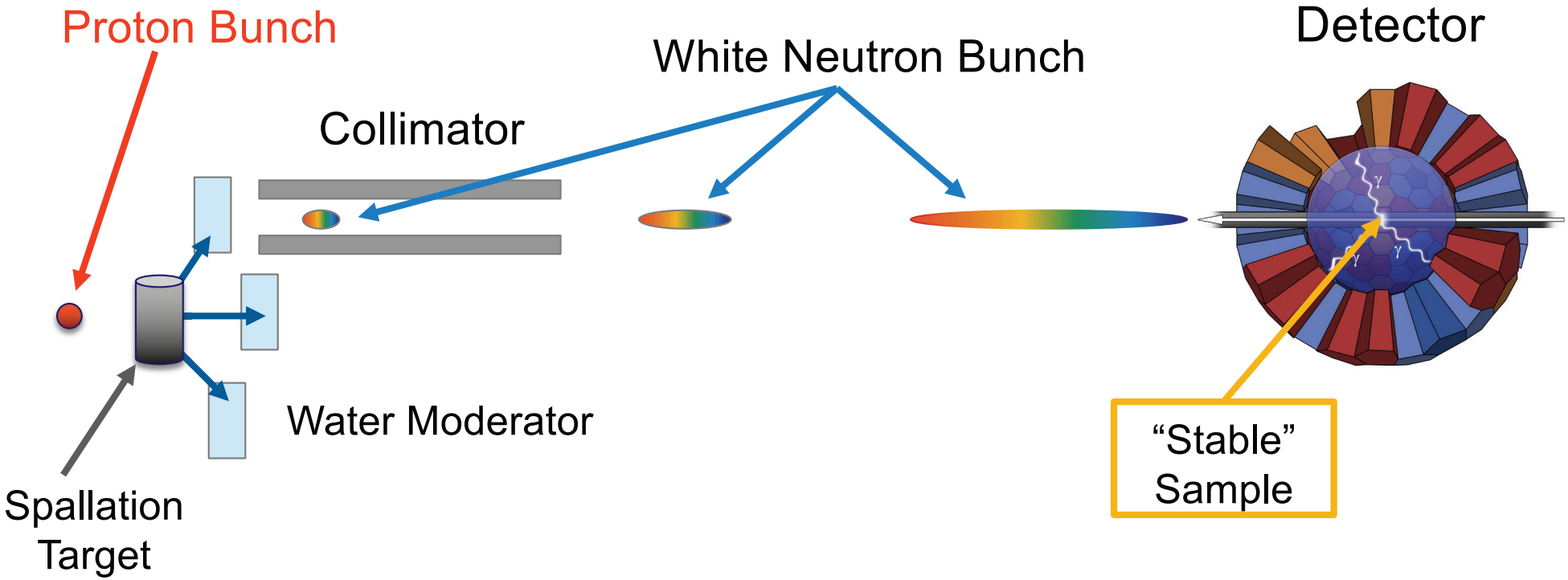
- Experimental ^{233}U(n,γ) cross section data in the literature are scarce and were measured decades ago.
- New report [1] suggests that a simultaneous measurement with capture would be useful.
- For ^{233}U fission is around one order of magnitude more likely than capture.
  - Good discrimination between gammas coming from capture and fission is required.
  - New measurement performed at LANL combining NEUANCE and DANCE.



^{233}U(n,γ) and ^{233}U(n,f) cross sections from ENDF/B-VIII.

[1] M.T. Pigni, R. Capote and A. Trkov, Annals of Nuclear Energy **163** (2021) 108595.

A Brief Reminder on Time-of-Flight Measurements

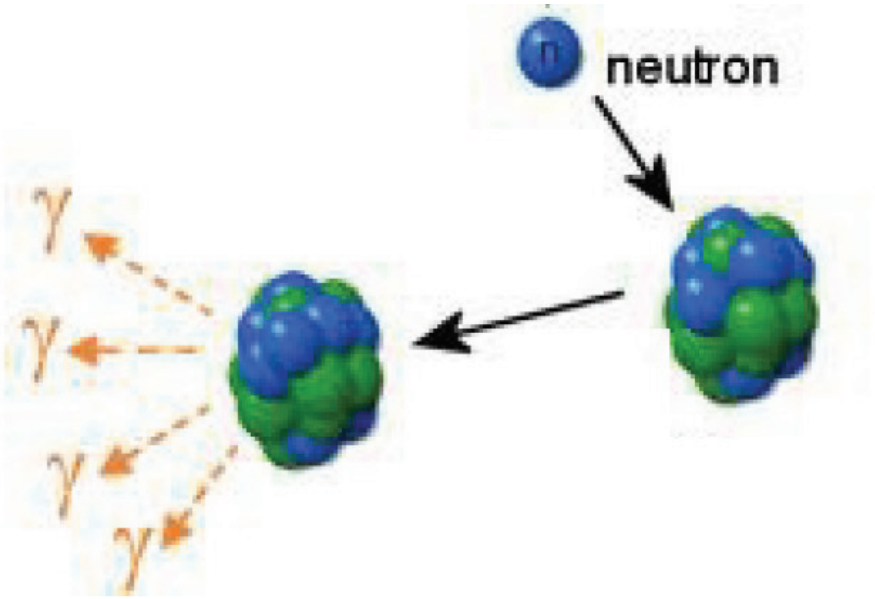


E_p= 800 MeV ν_p=20 Hz 10 meV < E_n < 500 keV

$\phi_n = 3 \cdot 10^5$ n/s/cm^2/decade

Details vary with facility, but the basic principles are the same

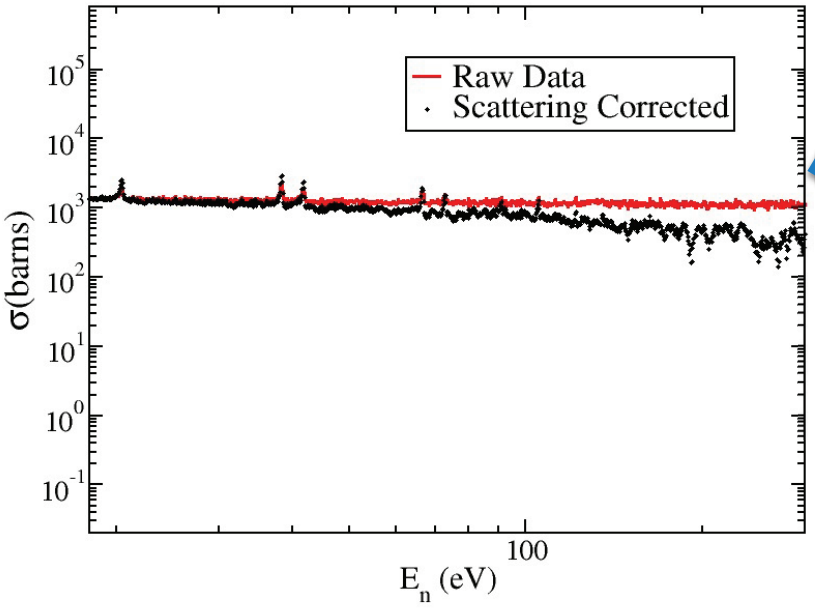
Signatures of Capture: Why Detectors Matter



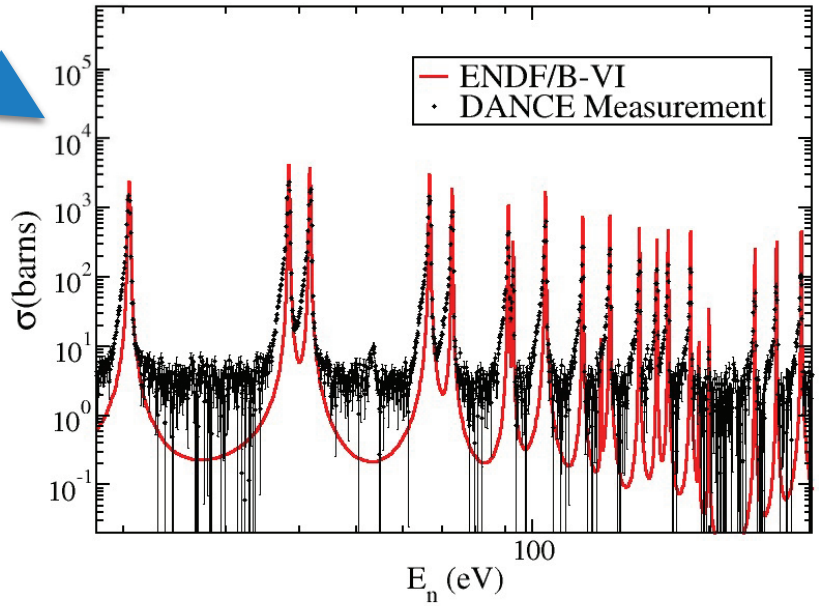
- Neutron Capture typically releases 6-10 MeV in gamma-ray energy
- Neutron energies do not significantly impact emitted energy

- Neutron capture measurements were often performed with C_6D_6 liquid scintillators
  - C_6D_6 has very low neutron sensitivity, but no gamma energy information
  - High Purity samples are always required
  - C_6D_6 has very low efficiency, typically requiring gram samples
- Calorimetric detectors can distinguish capture from decay based on total energy
  - High efficiency allows small samples
  - Isotopically mixed samples can be used if the isotopes have sufficiently different Q-Value
  - High segmentation offers gamma multiplicity information and limits individual crystal count rates

Greater than 2 order of magnitude improvement in S/N from DANCE cuts on Total Energy and Multiplicity



After Multiplicity and Total Energy Cuts



All data is from ^{240}Pu measurement

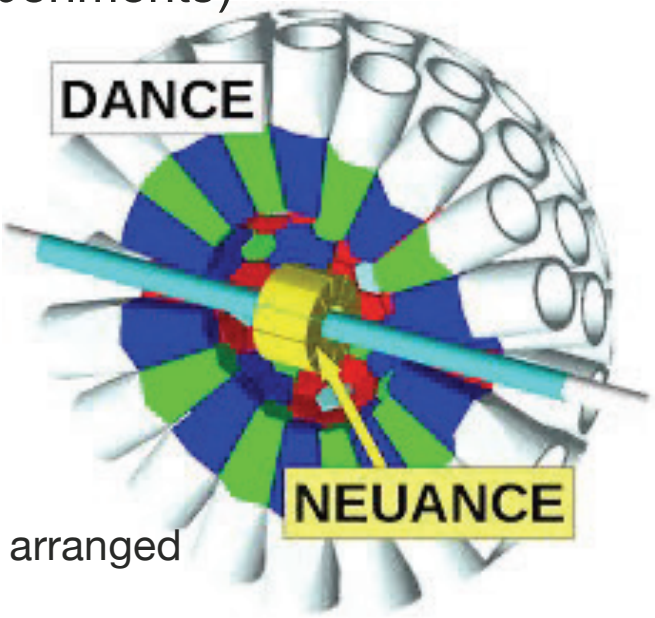
^{233}U Experiment at DANCE

- Uses the same fission:capture ratio technique used for ^{235}U (Jandel et al.) and ^{239}Pu (Mosby et al.)
- Used DANCE gamma calorimeter and NEUANCE fission tagger
- 20 mg sample of ^{233}U provided by the National Isotope Development Center
- Ran in 2 beam cycles
  - Proposal was highest ranked proposal for DANCE in both cycles
  - Nov/Dec 2020
    - 21 days of beamtime
  - June/July 2021
    - 19 days of beamtime

DANCE and NEUANCE

DANCE (**D**etector for **A**dvanced **N**eutron **C**apture **E**xperiments)

- $4\pi BaF_2$ **γ**-ray calorimeter composed by 160 crystals with an inner cavity of 17 cm radius [2].
- Used to measure neutron capture cross section data on small quantities of radioactive isotopes.
- We can measure E_n, E_{sum}, E_γ, and M_γ, providing more information than with C6D6 detectors.



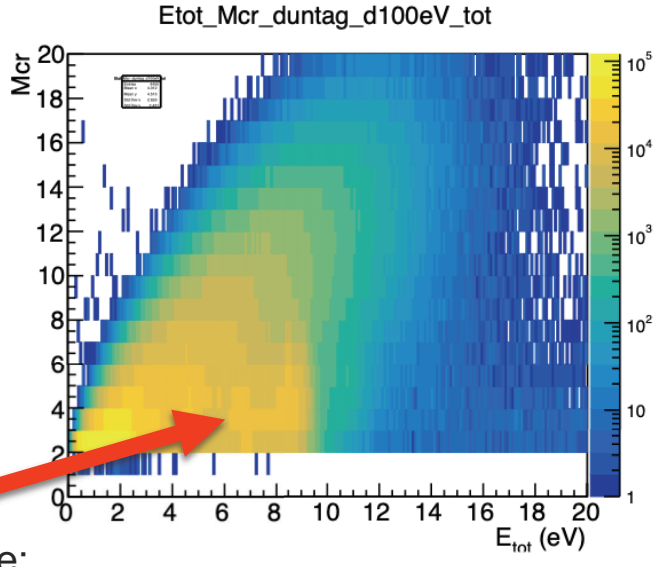
NEUANCE (**NEU**tron detector array at d**ANCE**)

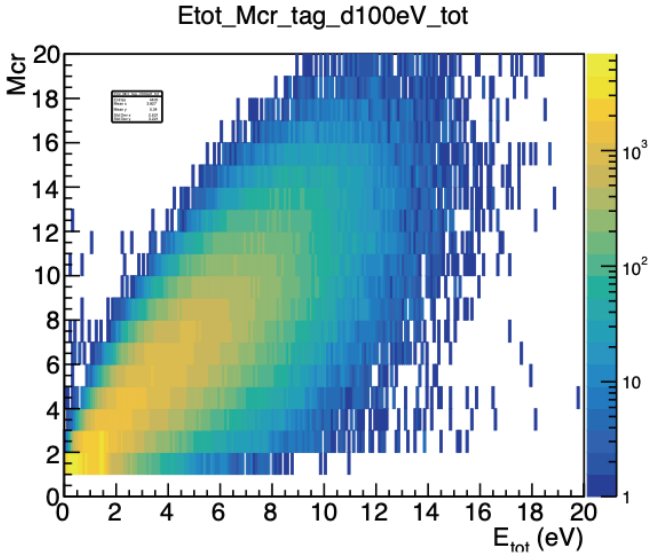
- Neutron detector array that consists in 21 stilbene crystals arranged in a cylindrical geometry around the beam pipe [3].
- Possibility to use a thick target.
- Used to detect neutrons coming from fission and determine by coincidence with DANCE, the gammas coming from fission.
- Those events are suppressed with a fission tag, and then the fission gamma shape is characterized with fission events to subtract the remaining fission background.

[2] M. Heil et al., Nucl. Instrum. Methods Phys. Res. A **459**, 229 (2001).
[3] M. Jandel et al. Nuclear Inst. and Methods in Physics Research, A **882** (2018) 105-113.

Fission Tagging allows clear identification—and elimination—of fission gamma background

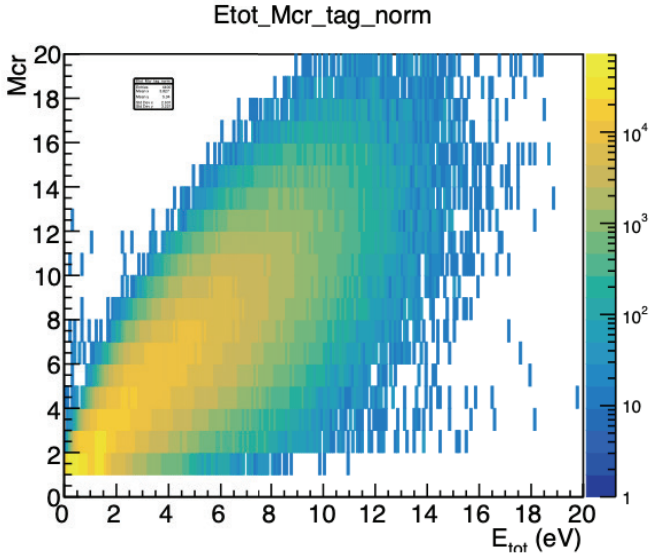
Raw Data

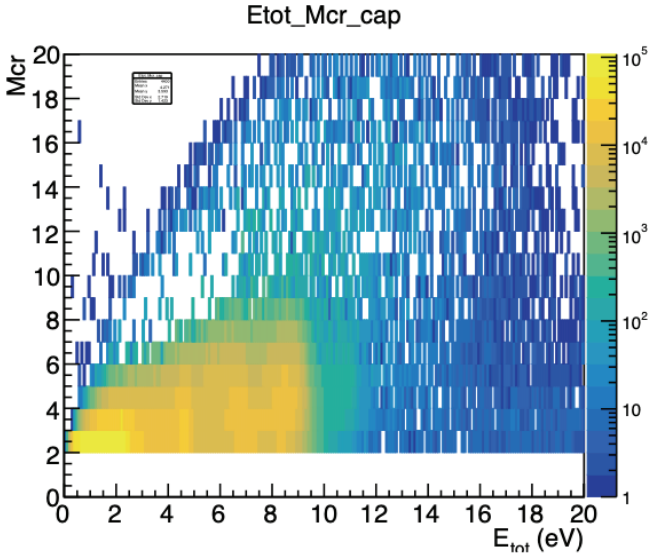




Isolated Fission Gammas

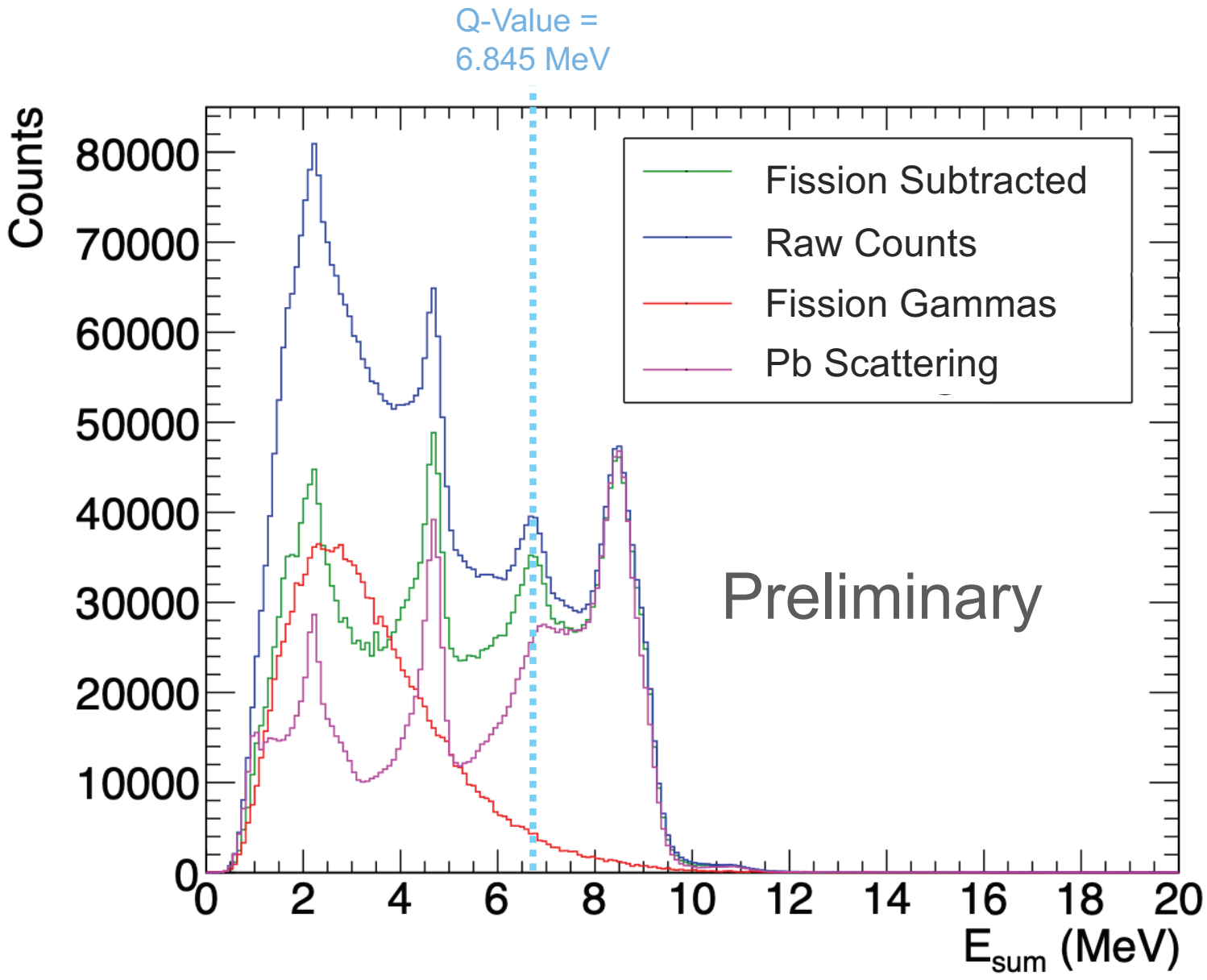
Capture Signature:
The Good Stuff





Fission Suppressed Gammas

DANCE analysis cuts allow identification and *isolation* of different reaction channels



Evaluation collaboration and next analysis steps

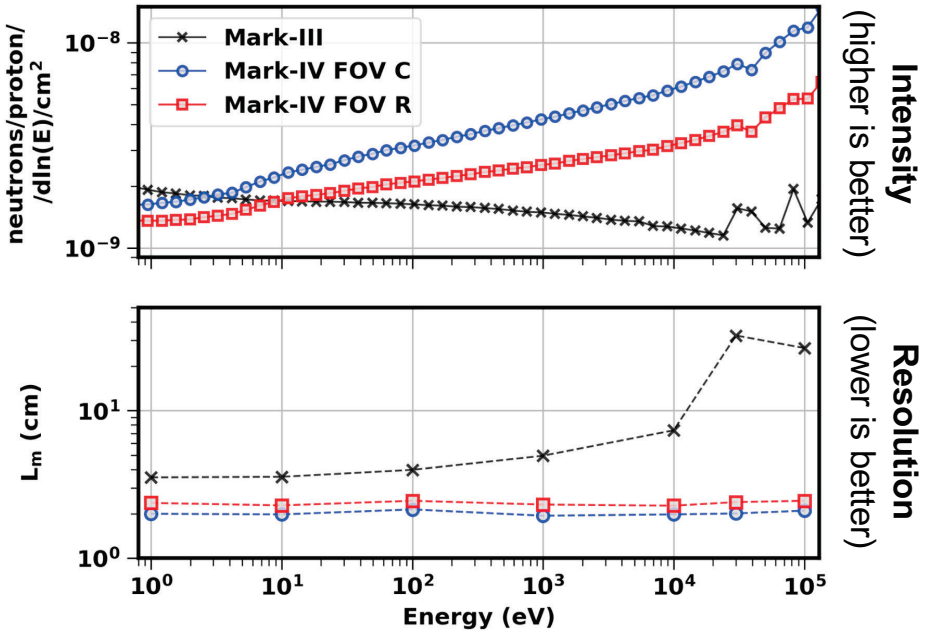
- We met with Luiz Leal and Marco Pigni in early December (virtually)
  - Measurement technique, strengths, limitations, optimal neutron binning
  - Timeline for results (preliminary numbers to them in summer, final in fall)
  - Planned future discussions ~ quarterly including a meeting before the TPR

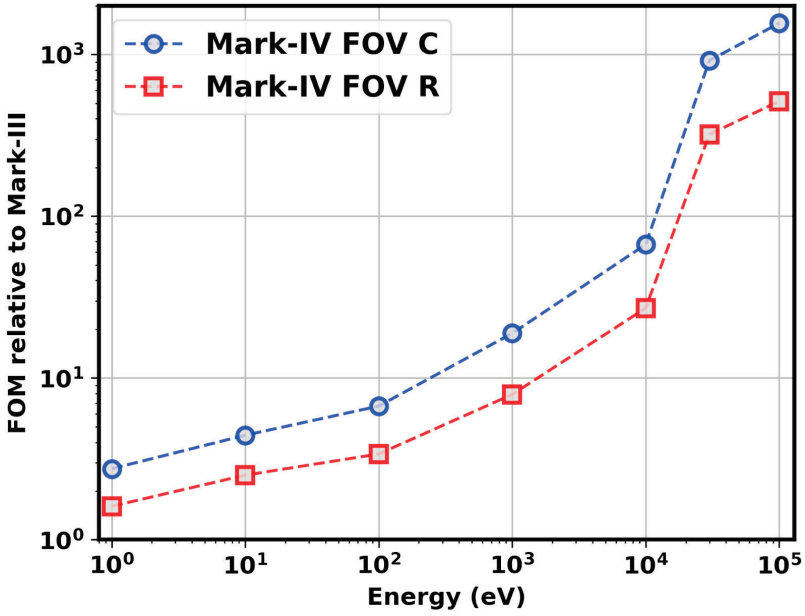
- Analysis
  - Optimize the fission tagging efficiency and acceptance
  - Extract capture yield
  - Determine capture cut efficiency

  - An independent determination of the fission and capture cross sections is possible, but would be a significant increase in the scope of work

The redesigned Lujan Target will enhance efficacy for keV cross sections

- Allow direct line-of-sight to W spallation target
- Improved intensity and resolution in the keV-MeV neutron energy range expand the range of measurements
  - Higher flux allows more flexibility for unstable isotopes
  - Improved resolution improves signal-to-noise in keV energy range

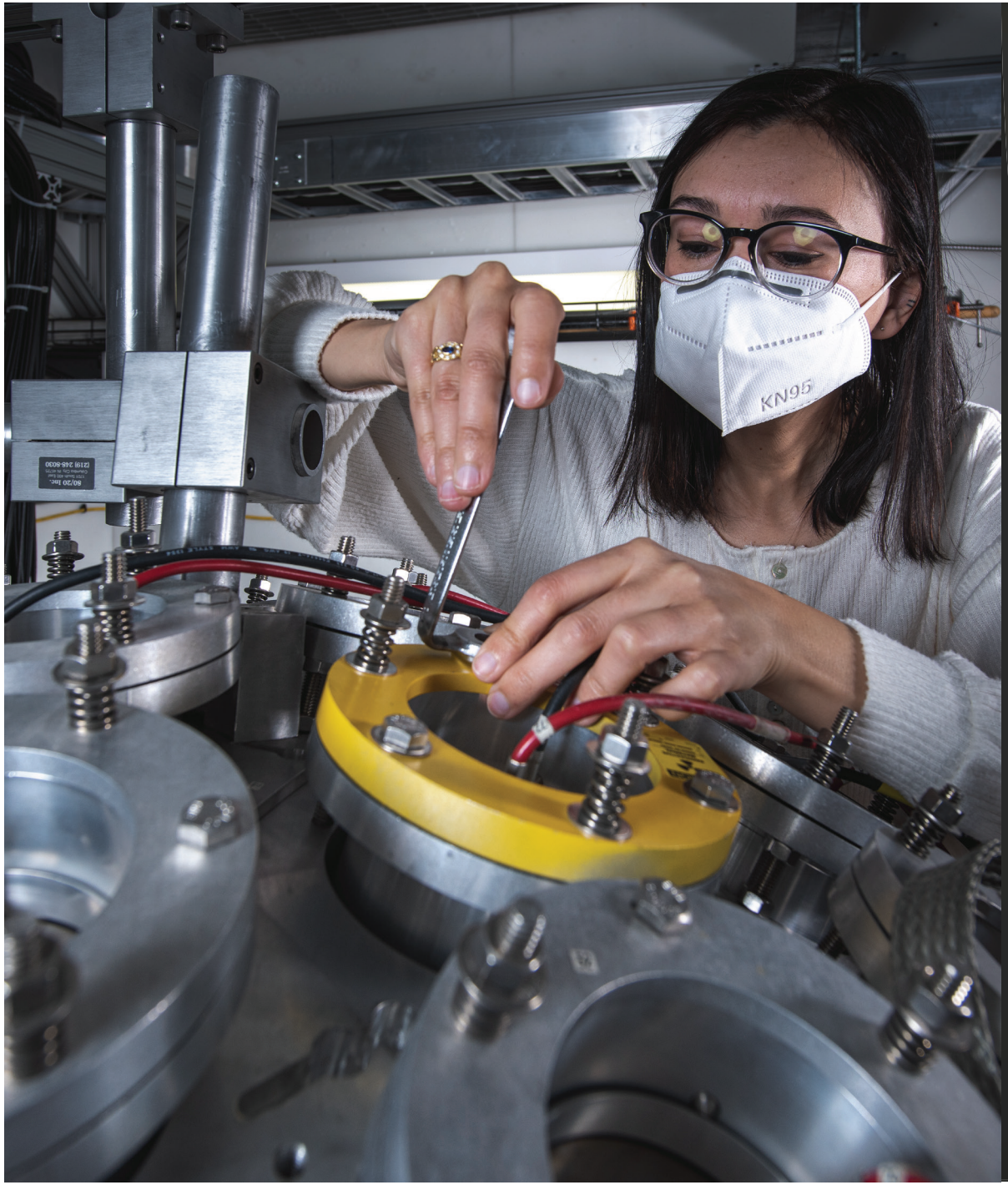




L. Zavorka, *et al. NIMA* **901** 189 (2018)

^{233}U(n,γ) Status and Prospects

- Capture measurements completed
  - Use of DANCE allows clean separation of capture, fission, and scattering channels
  - NEUANCE fission tagging with DANCE multiplicity gives reliable fission information
- Evaluation path and discussions are underway
  - Timeline for results (preliminary numbers to them in summer, final in fall)
  - Planned future discussions ~ quarterly including a meeting before the TPR
- Analysis is well underway to deliver a capture:fission ratio
  - An independent determination of the fission and capture cross sections is possible
- LANSCE neutron source improvements offer new measurement capability on small stable and radioactive samples



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